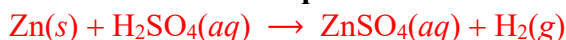


3.104 The carat is a unit of mass used by jewelers. One carat is exactly 200 mg. How many carbon atoms are in a 24-carat diamond?

$$24 \text{ carat} \times \frac{200 \text{ mg C}}{1 \text{ carat}} \times \frac{0.001 \text{ g C}}{1 \text{ mg C}} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} \times \frac{6.022 \times 10^{23} \text{ atoms C}}{1 \text{ mol C}} = \boxed{2.4 \times 10^{23} \text{ atoms C}}$$

3.107 An impure sample of Zn is treated with an excess of H<sub>2</sub>SO<sub>4</sub> to form ZnSO<sub>4</sub> and H<sub>2</sub>.

(a) Write the balanced equation for the reaction.



(b) If 0.0764 g of H<sub>2</sub> is obtained from 3.86 g of Zn, calculate the % purity of the Zn.

Find the mass of pure Zn needed to give this theoretical yield of H<sub>2</sub>.

$$0.0764 \text{ g H}_2 \times \frac{1 \text{ mol H}_2}{2.016 \text{ g H}_2} \times \frac{1 \text{ mol Zn}}{1 \text{ mol H}_2} \times \frac{65.39 \text{ g Zn}}{1 \text{ mol Zn}} = \boxed{2.48 \text{ g Zn}}$$

$$\text{percent purity} = \frac{2.48 \text{ g pure Zn}}{3.86 \text{ g impure Zn}} \times 100\% = \boxed{64.2\%}$$

(c) What assumptions must you make in (b)?

We assume that the impurities are inert and do not react with the sulfuric acid to produce H<sub>2</sub>.

3.131 The formula of a hydrate of barium chloride is BaCl<sub>2</sub> · xH<sub>2</sub>O. If 1.936 g of the hydrate gives 1.864 g of BaSO<sub>4</sub> upon treatment with sulfuric acid, calculate the value of x.

(HINT: BaCl<sub>2</sub> + H<sub>2</sub>SO<sub>4</sub> → BaSO<sub>4</sub> + 2 HCl)

Upon treatment with sulfuric acid, BaCl<sub>2</sub> dissolves, losing its waters of hydration.

$$1.864 \text{ g BaSO}_4 \times \frac{1 \text{ mol BaSO}_4}{233.4 \text{ g BaSO}_4} \times \frac{1 \text{ mol BaCl}_2}{1 \text{ mol BaSO}_4} \times \frac{208.2 \text{ g BaCl}_2}{1 \text{ mol BaCl}_2} = 1.663 \text{ g BaCl}_2 \text{ (anhydrate)}$$

$$\text{Mass of water} = (1.936 \text{ g} - 1.663 \text{ g}) = 0.273 \text{ g H}_2\text{O}.$$

$$0.273 \text{ g H}_2\text{O} \times \frac{1 \text{ mol H}_2\text{O}}{18.02 \text{ g H}_2\text{O}} = 0.0151 \text{ mol H}_2\text{O}; 1.663 \text{ g BaCl}_2 \times \frac{1 \text{ mol BaCl}_2}{208.2 \text{ g BaCl}_2} = 0.00799 \text{ mol BaCl}_2$$

$$x = \frac{0.0151 \text{ mol H}_2\text{O}}{0.00799 \text{ mol BaCl}_2} = 1.89, \text{ which rounds up to } x = 2 \text{ (BaCl}_2 \cdot 2\text{H}_2\text{O)}$$

3.134 When 0.273 g of Mg is heated strongly in an N<sub>2</sub> atmosphere, a chemical reaction occurs. The product has a mass of 0.378 g. Calculate the empirical formula of the compound, containing only Mg and N and name it.

$$? \text{ g N} = 0.378 \text{ g Mg}_x\text{N}_y - 0.273 \text{ g Mg} = 0.105 \text{ g N}$$

$$0.273 \text{ g Mg} \times \frac{1 \text{ mol Mg}}{24.31 \text{ g Mg}} = 0.0112 \text{ mol Mg} \div 0.00749 = 1.5 \times 2 = 3$$

$$0.105 \text{ g N} \times \frac{1 \text{ mol N}}{14.01 \text{ g N}} = 0.00749 \text{ mol N} \div 0.00749 = 1 \times 2 = 2$$

} Mg<sub>3</sub>N<sub>2</sub>, magnesium nitride

**3.136** The anti-knock additive in leaded gasoline contains only C, H, and Pb. When 51.36 g of this compound is burned in an apparatus like that in Figure 3.6, 55.90 g of CO<sub>2</sub> and 28.61 g of H<sub>2</sub>O are produced. Determine the empirical formula of the additive.

$$? \text{ g C} = 55.90 \text{ g CO}_2 \times \frac{1 \text{ mol CO}_2}{44.01 \text{ g CO}_2} \times \frac{1 \text{ mol C}}{1 \text{ mol CO}_2} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} = 15.25 \text{ g C}$$

$$? \text{ g H} = 28.61 \text{ g H}_2\text{O} \times \frac{1 \text{ mol H}_2\text{O}}{18.02 \text{ g H}_2\text{O}} \times \frac{2 \text{ mol H}}{1 \text{ mol H}_2\text{O}} \times \frac{1.008 \text{ g H}}{1 \text{ mol H}} = 3.201 \text{ g H}$$

$$\text{mass Pb} = 51.36 \text{ g} - (15.25 \text{ g C} + 3.201 \text{ g H}) = 32.91 \text{ g Pb}$$

$$15.25 \text{ g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 1.270 \text{ mol C} \div 0.1588 \approx 8$$

$$3.201 \text{ g H} \times \frac{1 \text{ mol H}}{1.008 \text{ g H}} = 3.176 \text{ mol H} \div 0.1588 \approx 20$$

**PbC<sub>8</sub>H<sub>20</sub>** [This is tetraethyl lead, Pb(C<sub>2</sub>H<sub>5</sub>)<sub>4</sub>]

$$32.91 \text{ g Pb} \times \frac{1 \text{ mol Pb}}{207.2 \text{ g Pb}} = 0.1588 \text{ mol Pb} \div 0.1588 = 1$$

**Additional Questions:**

**A.** 0.755 g sample of hydrated copper(II) sulfate is heated carefully until it had changed completely to anhydrous copper(II) sulfate with a mass of 0.483 g. Determine the value of x in the formula of the hydrate, CuSO<sub>4</sub> · x H<sub>2</sub>O. What would you have done in the lab to be sure that no water was left in the sample after heating?

$$? \text{ moles CuSO}_4 = 0.483 \text{ g CuSO}_4 \times \frac{1 \text{ mol CuSO}_4}{159.62 \text{ g CuSO}_4} = 0.00303 \text{ mol CuSO}_4$$

$$? \text{ g H}_2\text{O} = 0.755 \text{ g CuSO}_4 \cdot x \text{ H}_2\text{O} - 0.483 \text{ g CuSO}_4 = 0.272 \text{ g H}_2\text{O}$$

$$? \text{ mol H}_2\text{O} = 0.272 \text{ g H}_2\text{O} \times \frac{1 \text{ mol H}_2\text{O}}{18.02 \text{ g H}_2\text{O}} = 0.0151 \text{ mol H}_2\text{O}$$

$$x = \frac{0.0151 \text{ mol H}_2\text{O}}{0.00303 \text{ mol CuSO}_4} = 4.98 \approx 5, \text{ CuSO}_4 \cdot 5 \text{ H}_2\text{O}, \text{ copper(II) sulfate pentahydrate.}$$

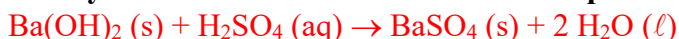
To be sure no water remained after heating, you could heat the sample several times and mass it after each heating, until the mass after heating remained constant, indicating that no more water was present to drive off.

**B.** Write the balanced chemical equation for the following reactions:

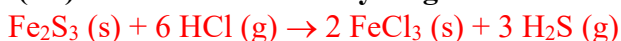
i. calcium metal reacts with water to produce aqueous calcium hydroxide and hydrogen gas.



ii. barium hydroxide reacts with sulfuric acid to produce barium sulfate and water.

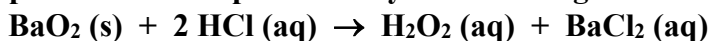


iii. iron(III) sulfide reacts with hydrogen chloride to form iron(III) chloride and hydrogen sulfide.



iv. carbon disulfide reacts with ammonia to produce hydrogen sulfide and ammonium thiocyanate.



**C. Hydrogen peroxide can be produced by the following reaction:**

i. What is the theoretical yield (in grams) of hydrogen peroxide when 1.50g of barium peroxide is treated with 25.0 mL of a hydrochloric acid solution containing 0.0272g of HCl per mL?

$$\frac{1.50 \text{ g BaO}_2 \times \frac{1 \text{ mol BaO}_2}{169.33 \text{ g BaO}_2}}{1} = \frac{0.00886 \text{ mol BaO}_2}{1} = 0.00886 \text{ mol Rxn}$$

$$\frac{25.0 \text{ mL HCl solution} \times \frac{0.0272 \text{ g HCl}}{1 \text{ mL HCl solution}} \times \frac{1 \text{ mol HCl}}{36.46 \text{ g HCl}}}{2} = \frac{0.0187 \text{ mol HCl}}{2} = 0.00933 \text{ mol Rxn}$$

$$\text{TY H}_2\text{O}_2 = 0.00886 \text{ mol Rxn} \times \frac{1 \text{ mol H}_2\text{O}_2}{1 \text{ mol Rxn}} \times \frac{34.02 \text{ g H}_2\text{O}_2}{1 \text{ mol H}_2\text{O}_2} = \boxed{0.301 \text{ g H}_2\text{O}_2}$$

ii. How many moles of the excess reactant are left unreacted?

$$0.00886 \text{ mol Rxn} \times \frac{2 \text{ mol HCl}}{1 \text{ mol Rxn}} = 0.0177 \text{ mol HCl used}$$

$$? \text{ g HCl remaining} = 0.0187 \text{ mol HCl} - 0.0177 \text{ mol HCl} = \boxed{0.010 \text{ mol HCl}}$$

**D. Methyl isothiocyanate (MITC), an organosulfur compound which contains only C, H, N, and S, is used in agriculture as a soil fumigant, mainly for protection against fungi and nematodes. Find the empirical formula for MITC if combustion analysis of a 0.2415-g sample gives 0.2907 g CO<sub>2</sub>, 0.08926 g H<sub>2</sub>O, a mixture of nitrogen oxides, and 0.2116 g SO<sub>2</sub>.**

$$? \text{ g C} = 0.2907 \text{ g CO}_2 \times \frac{12.01 \text{ g C}}{44.01 \text{ g CO}_2} = 0.07933 \text{ g C}$$

$$? \text{ g H} = 0.08926 \text{ g H}_2\text{O} \times \frac{(2)(1.008 \text{ g H})}{18.02 \text{ g H}_2\text{O}} = 0.009886 \text{ g H}$$

$$? \text{ g S} = 0.2116 \text{ g SO}_2 \times \frac{32.07 \text{ g S}}{64.07 \text{ g SO}_2} = 0.1059 \text{ g S}$$

$$? \text{ g N} = 0.2415 \text{ g MITC} - (0.07933 \text{ g C} + 0.009886 \text{ g H} + 0.1059 \text{ g S}) = 0.0463 \text{ g N}$$

$$? \text{ mol C} = 0.07933 \text{ g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 0.006605 \text{ mol C}$$

$$? \text{ mol H} = 0.009886 \text{ g H} \times \frac{1 \text{ mol H}}{1.008 \text{ g H}} = 0.009907 \text{ mol H}$$

$$? \text{ mol N} = 0.0463 \text{ g N} \times \frac{1 \text{ mol N}}{14.01 \text{ g N}} = 0.00330 \text{ mol N}$$

$$? \text{ mol S} = 0.1059 \text{ g S} \times \frac{1 \text{ mol S}}{32.07 \text{ g S}} = 0.003302 \text{ mol S}$$

Dividing each quantity by 0.00330 mol gives **C<sub>2</sub>H<sub>3</sub>NS** as the empirical formula.